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A STUDY ON AIRBORNE INTEGRATED DISPLAY SYSTEM AND HUMAN INFORMATION PROCESSING

K. Mizumoto, H. Iwamoto, S. Shimizu, & I. Kuroda

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16. Abstract

Two experiments using the static models of modified Electronic Attitude Director Indicator (EADI) of Airborne Integrated Display (AID) were conducted in order to assess the cognitive characteristic of pilots.

Experiment I: The time to memorize, as quickly and perfectly as possible, the contents of eight models.

Experiment II: The contents of five models to be memorized were measured within two 5 second presentation with a 30 second interval.

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A STUDY ON AIRBORNE INTEGRATED DISPLAY SYSTEM AND HUMAN INFORMATION PROCESSING

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I. Introduction

In recent years, ways to reduce the workload of airplane pilots and enhance safety by a systematic integrated display of information, which is obtained by airborne instruments, have been studied. The most important role has been played by the great progress of computers in terms of data processing capacity, dependability and the speed of operation processing and the like, accompanied by the development of smaller and lighter computers. /78*

That is, the major information obtained by airborne instruments, which had been hitherto displayed separately and mechanically, is to be operation processed by computer so as to be integrated through a processor and displayed in color on CTR.

B-767, the fourth-generation passenger jet plane, is the first commercial passenger airliner equipped with an airborne integrated display system. The merits of the integrated display system are that the major information displayed in one spot can reduce the necessary amount of scanning, and consequently the workload, in terms of visually obtained information, and also that the preprocessing of information by the processor can select the least information that is directly needed to make judgements. Nevertheless, because various information displayed simultaneously might possibly cause confusion, it is necessary to process information.

In this article, the problems of information obtained by the airborne integrated display system and human visual cognition are focussed on for examination.

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*Numbers in the margin indicate pagination in the foreign text.

II Experiment

The reading of digital, analogue, and digital-analogue information is examined by using static models of ILS (Instrument Landing System), referring to EADI (Electronic Attitude Director Indicator), a kind of airborne integrated display, with which the B-767 is equipped. In addition, we tried to make the contents of the models similar to the data used at the beginning of this study as much as possible. However, since it was not stable in terms of symbology, the displays might not have been reproduced as they should have been in terms of luminousness and color.

Experiment (I) to measure the time needed to memorize the contents of models, and experiment (II) to measure the contents which can be memorized within a limited time were conducted. The details of the experiments are described as follows. /79

1. Experiment (I)

(1) Making the models

As shown by Figure 1, the following 9 items were displayed in black ink on a high quality white paper of these dimensions: length 14 cm X width 15.3 cm, with green trim whose width is 1.5 cm.

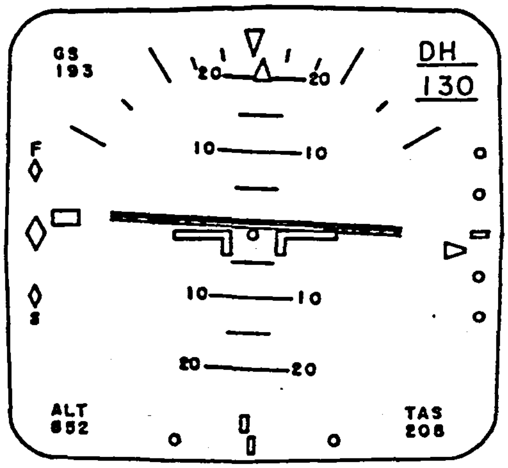

Fig. 1 Static model of electronic attitude director indicator of airborne integrated display (example for condition 8).

DH: Decision height Digital (feet)
GS: Ground Speed Digital (knot)
TAS: True Air Speed Digital (knot)
ALT: Altitude Digital (feet)
Pitch: Analogue-digital (degree, indicated as the relationship between the miniature aircraft and the horizon)
Bank: Analogue-digital (same as the above)
Error in Speed: Analogue (slow or fast should be indicated on the right side of the screen)

Error in glide slope: Analogue (high or low should be indicated on the right side of the screen)

Aberration of course: Analogue (right or left should be indicated on the right side of the screen)

The models of combinations of these nine items were made. One of them was to explain to the subjects the contents of the display, two were for training, and the other eight models were used for the experiment(condition 1 - condition 8). The contents of the display are shown in Table 1. In addtion, Figure 1 is used for experiment condition 8.

Tab. 1 Contents of static models used in the experiments (models conditioned from 3 to 5 were not used in Exp. II).

[illegible]	Condition	DH	GS	TAS	ALT	Pitch	Bank	Speed	G.Slope	Course
1	Training 1	170	155	152	353	5° Up	5° Right	Slow	Above	Left
2	〃 2	180	168	172	257	5° Down	20° R.	Normal	A.	L.
LATIN SQUARE	1	100	150	150	100	0°	0°	N.	Normal	Normal
	2	150	150	155	900	5° U.	0°	N.	N.	N.
	3	140	155	150	750	10° U.	5° Left	N.	N.	N.
	4	130	153	148	537	5° U.	10° R.	N.	N.	N.
	5	120	165	170	650	0°	0°	Fast	A.	Right
	6	110	150	145	350	0°	5° R.	N.	N.	L.
	7	140	140	135	420	7° U.	5° L.	S.	A.	R.
	8	130	193	208	852	2° D.	3° L.	F.	Below	L.

(2) Method of Presentation /80

The experimenter presented models one by one at observation distance of 70 cm, and at a 25° angle below the subject's level gaze. The order of presentation was the same in the explanation and training for each subject, and after that, in experiment, by using the latin square method, a different order was arranged for each subject. Moreover, the periphery and background of the presenter were covered with a black flock paper, and the surface of the instrument models was lighted by about 500 lx from behind the subject, who was sitting on a chair, by photographing lamps(300W x 2 lamps).

(3) Subjects

The subjects were 8 pilots, all males, age 27 - 49 years old (the average age 39.9 years old) who passed the aviational physical examination. Their flying hours were 1,200 - 4,900 hours (the average 3,298 hours).

(4) Memorization Time

The items were explained to the subjects using the models; they were instructed to show the condition of landing by ILS (Instument Landing System) and to memorize the contents as accuratly and quickly as possible. In addition, the instructions and explanation were tape-recorded by the experimentor in advance. Both negative and positive pole terminals were attached to both corners of the subject's eyes, and an EOG electric terminal was attached to the center of his forehead for the purpose of electrically grounding the subject. The device fixed on the subject's face was designed to restrict the movement of his head. The subject's eyes were closed while the experimenter was changing the models and opened with the experimenter's calling a signal, "ready". Then, the model was still covered so that the subject could not know the contents. Next, when the experimeter called, "look to the left", the subject, pushing a button with his right hand,stared at a red mark located at a point about 60° above. During that time, the experimenter uncovered the model and gave the subject the sign, "OK". The subject pushed the button again, returned his eyes to the right, and memorized the contents of the display. After memorizing the contents, the subject pushed the button, and returned his eyes to the left. At the same time, the experimenter covered the model. The memorized contents were immediately recorded into a taperecorder.

The time in which the subject stared at the model was measured by recording on a pen-drawing oscillograph the signals from EOG and the push button. In this way, the time needed to memorize each one of the eight models was measured. It took about 45 minutes per subject to complete the experiment which included the explanation, attaching the electric terminals, and training.

(5) Result

The mean time to memorize each model and the average number of errors in experiment (I) are shown in Figure 2. Clear differences are recognized according to the displayed contents. Consequently, it is thought that the degrees of difficulty in the contents had a great impact on the result. In condition 1, it took an average of 11.1 seconds for 9 items to be memorized, whereas condition 8 took the longest time, an average of 67.9 seconds, to be memorized. The result of analyzing the variance is shown in Table 2 and significant differences among the conditions as well as the subjects ($p < .01$ for both) were recongnized. The latter indicates differences in ability to memorize among the subjects.

Moreover, the analysis of the errors indicates that, besides the difference in condition, the difference in the order of presenting the models also tends to cause different result. That is, the models whose contents were difficult or which were presented in the beginning got more errors. Therefore, it is thought that it takes a little practice to memorize these kinds of models. There should have been a few more trainings. In addition, condition 5 was memorized very quickly though it got more errors.

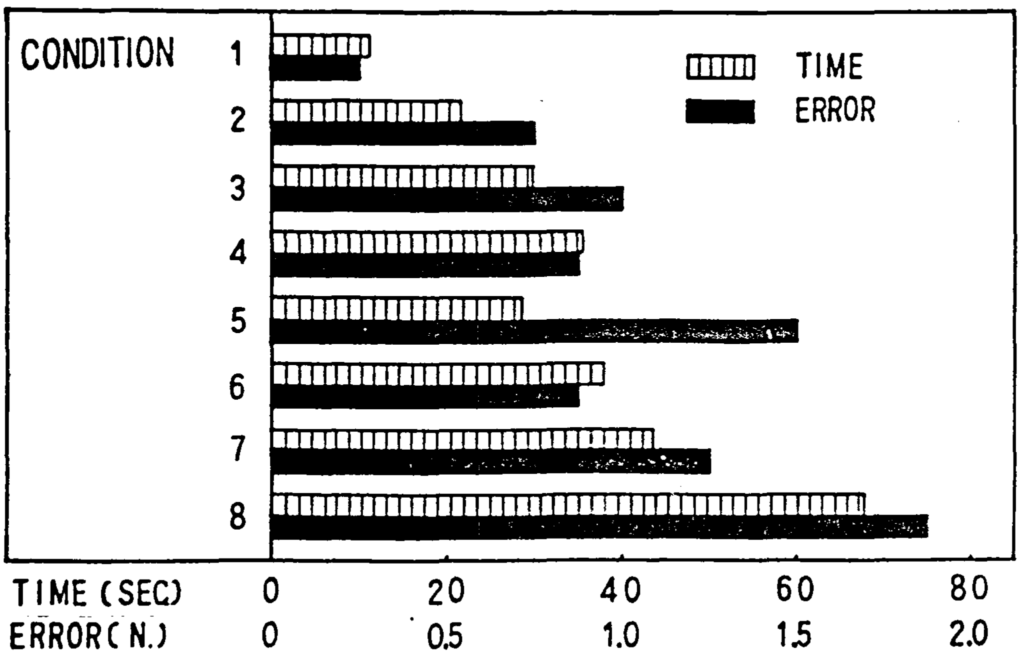

Fig. 2 Mean time to memorize each model and the average number of errors in Exp. I.

Furthermore, among the subjects there were significant differences (X^2=24,912, $X.01(7)^2$=18,476) in their perfomances. The faster the subjects memorized the contents, the more errors they commited.

Tab.2 Analysis of variance of time to memorize models in Exp. I.

S V	S S	DF	M S	F.
Subject	9088.30	7	1298.33	8.682**
Sequence	983.48	7	140.50	0.940
Condition	15888.55	7	2269.79	15.178**
Error	6280.78	42	149.54	
Total	32241.11	63	511.76	

** P< .01

2. Experiment (II)

(1) Instrument Models

After the trainings, which were increased to 3 times from 2 times, using the same models that were used for experiment (I), only the 5 kinds of models, conditions 1,2,6,7, and 8, were used for experiment (II). /81

(2) Method of Presentation

In order to measure the contents of the model memorized within a fixed amount of time (5 seconds x 2 times, a 30 seconds interval between them), the lamps were switched on and off by a timer. That is, the experimenter set up a model so that the lamps were off (the degree of illumination on the surface of model: below 0.11 lx). When the experimenter called a sign, the lights were switched on by the timer for 5 seconds, in which time the subject memorized the contents of the display. During 30 seconds after the lights were turned off, the subject verbally recalled the contents he had memorized. After the 30 seconds, the lights were again turned on for 5 seconds, during which the subject memorized the same displayed contents and again orally recalled it after the lights were turned off. In this case, since there was a possibility that the subject either had a different memory from the first one or had fogotten

the first one, the subject was asked to say everything he had memorized. After the second answer, the experimenter set up the next model.

As described above, the contents memorized were measured in the order determined by the latin square method for each subject. In addition, the observation distance and the like were the same as in experiment (I). However, in experiment (II), the EOG electric terminal was not attached to the subject.

(3) Subjects /82

The subjects were 5 pilots, all males, age 23 - 33 years old (the average age 26.2 years old), who did not participate in experiment (I). Their flying hours were 410 - 1,300 hours (the average=796 hours).

(4) Recording of the Memory

As in experiment (I), each subject had the displayed contents explained to him, and was instructed to memorize, in the order of the contents, what he thought was the most important at the time of landing. The contents recalled by the subject were taperecorded, and the time that the lamps were switched on and off and the audio signals of the subject's voice were recorded into the pen-drawing oscillograph to be analyzed later.

The experiment took 30 minutes per subject including the explanation and the training.

(5) Result

Figure 3 shows the mean values of the percentages of correct answers to the two 5 second-presentations per condition among the 5 subjects. In the second 5 second-presentation (total 10 second-presentation), due to the differences in the models, namely the differences in the degrees of difficulty, different results were obtained. Condition 1 got about 8 correct answers (88.8%) among 9 items, whereas condition 8 got only 4.4 correct answeres (48.8%) on the average. Moreover,

after the second 5 second-presentations, on the average, condition 1 got 9 correct answers (100%), while condition 8 got 6.4 correct answers (71.1%). The result of the analysis of the variance in the percentage of correct answers is shown in Table 3. For both 5 second-presentations, a statistically significant difference was recongnized only in the differences among the conditions of the models.

The number of missed and erroneous items of the models for all 5 subjects are shown in Table 4. The number of missed items decreased after the second presentations from the first ones on the whole. Particularly, condition 1 was not missed at all after the second presentations as described before. In general, there were more errors for the items which included digital information such as GS, whereas there were fewer errors for the items of analogue information such as error in speed. However, since the subjects were instructed to memorize from the items that they thought the most important, GS, which is not so important, may have been hard to memorize, /83

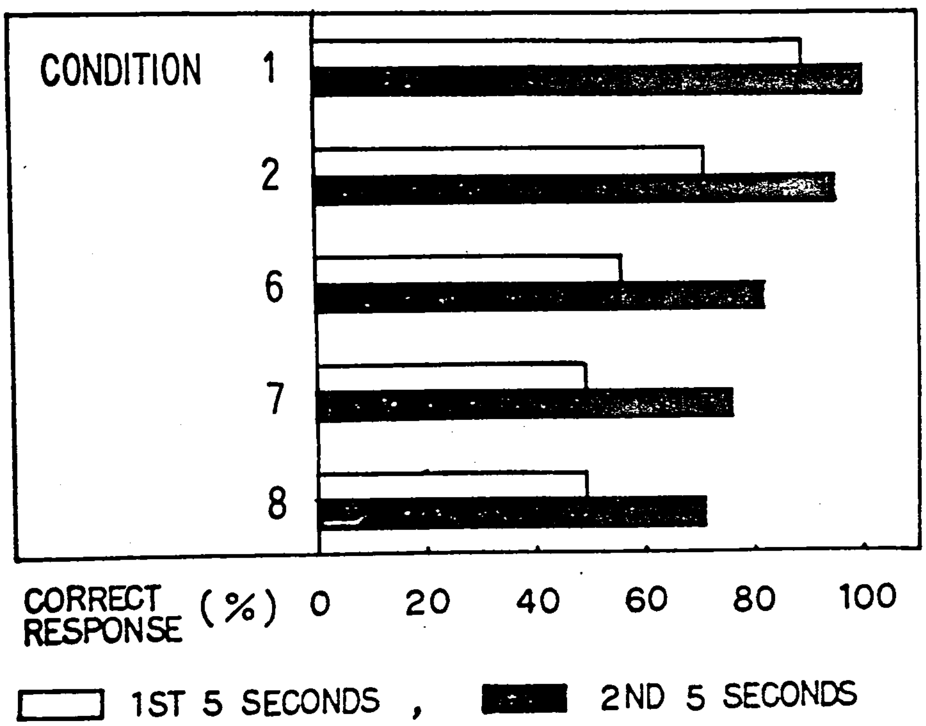

Fig. 3 Mean percentages of correct-responded items of the models used in Exp. II.

Tab. 3 Analysis of variance in the percentages of correct-responded items in Exp. II.

(1) 1ST 5 SECONDS

S V	S S	D F	M S	F_0
Subject	17.36	4	4.34	2.881
Sequence	8.16	4	2.04	1.354
Condition	48.16	4	12.04	7.991**
Error	18.08	12	1.51	
Total	91.76	24		

(2) 2ND 5 SECONDS

S V	S S	D F	M S	F_0
Subject	14.96	4	3.74	2.539
Sequence	7.76	4	1.94	1.317
Condition	25.36	4	6.34	4.304*
Error	17.68	12	1.47	
Total	65.76	24		

* $P<.05$, ** $P<.01$

Tab. 4 The number of missed and erroneous items of the models in Exp. II (for all 5 subjects).

Condition		DH	GS	TAS	ALT	Pitch	Bank	Speed	G.Slope	Course	Σ
1	1st	2	2		1						5
	2nd										
2	1st	2	3	2	1	3	1	1			13
	2nd			1		1					2
6	1st	2	3	4	5	3	2			1	20
	2nd	1	3	1	2		1				8
7	1st	2	4	3	4	3	2	1	1	3	23
	2nd	2	1	1	1	2	1		1	2	11
8	1st	3	4	1	4	4	2	1	2	2	23
	2nd	2	3	3	2	1		1		1	13
Σ	1st	11	16	10	15	13	7	3	3	6	84
	2nd	5	7	6	5	4	2	1	1	3	34

III Review

The attempt to reduce the workload of airplane pilots by computer processing airborne instrument information through CRT can be said to originate from HUD (Head Up Display).

The major cause of the reduction in the workload can be found in the lightening of neurophysiological burdens such as adjustment and convergence, accompanied by the movement of both eyes, and the burden on the nerve center, by expediting comparison and examination of major /84 information. However, we can not assert that there is no problems for these merits. For instance, the affect of VDT (Visual Display Terminal) using CRT on human visual function is becoming a grave social problem. Moreover, as for the burden on the nerve center, as long as there is a limit in human capacity to process information, it is not easy to find an adequate method in relation to the amount of information.

In examining the human information processing capacity in terms of short memory of the displayed contents, as in this article, there are aspects which can not be understood by generally examining the merits and demerits of digital and analogue information. That is, it is necessary to express a visual stimulus in which digital and analogue information coexist as an amount of information in an actual numerical value.

The amount of information that can be processed by a human being was mentioned by Oestreicher, H. L. (1967)[9] and Sakkit, B. (1972)[10]. However, their analyses were based on the excitement of visual cells and photons as units, and are not suitable for an analysis on the macro level as in this experiment. Therefore, we attempted to analyze and examine it based on the amount of visual information in a more practical situation.

By the way, it is desired to fix the time in which a stimulus is presented. For instance, in experiment (I), the subjects were all instructed to memorize as quickly and accurately as possible, though in fact there were subjects who memorized fast and subjects who did

not and the former tended to make more errors. The trade off between time and accuracy like this was recognized in the conditions of the models. Despite condition 5 being memorized very fast, it got more errors. This is related to the personalities of the subjects and is itself a very interesting subject. Nevertheless, since it does not relate to the objective of this analysis, it will not be discussed further.

It is very difficult to estimate the amount of information that was actually processed at the nerve center, when there are treacherous memories, and variations between individuals in the time needed for memorization itself. On the other hand, in experiment II there was not much recognizable difference between the subjects. Therefore, the main object of the analysis is the result of the study of the memorized contents.

Among conditions 1,2,6,7, and 8, both conditions 1 and 2 had no deviations between the items set by ILS, having the same analogue information and different digital information. On the other hand, for condition 6,7, and 8 both digital and analogue information become gradually more intricate. In order to measure and compare the amounts of information, the displayed contents were converted into the value equivalent to bit (hereinafter referred to as bit).

There are two kinds of readings done by a pilot: check read, which is to confirm that the indicated value is the fixed value, and read out, which is to read the indicated value. Since the subjects already knew that the experiments were set up at landing using ILS, they could presume that DH should be about 100 - 200 feet, GS and TAS should be about 100 - 200 knots. Consequently, the check read should be to confirm that the numerical value at the 100 decimal is 1, and in this case the amount of information was calculated thus: whether 0 or not (1 bit); if not 0 then which one of the other 9 kinds? (3.2 bits). By the above mentioned calculation, for instance, 100, 150, 148 become 3, 6.2 and 9.4 bits respectively. However, concerning ALT, there is a possiblity for the 100 decimal to change variably. Therefore, for ALT, the 100 decimal is 4.2 bits, and 10 and 1 decimals are calculated

as for DH and the like.

On the other hand, concerning the analogue-digital information such as pitch and the like, the amount of information was calculated as follows: whether above 0°, at 0° or below 0° (1.6 bits), if above 0° whether it is 10° or 20° (1 bit); or whether it is between those values (1 bit); or whether it is between half of those values (2 bits).

Furthermore, concerning the pure analogue information such as error in speed and the like it was calculated as: whether it is slow, normal, or fast (1.6 bits); if it is late, in what degree (2 bits). The amount of information calculated in the way mentioned above is shown is Table 5.

As seen in Figure 3, variances in the number of items memorable to the subjects due to the degrees of difficulty were recognized. However, the observation time was fixed at 5 seconds each before and after the 30 second-interval. The time, 5 seconds, is proper for the time for the pilots eyes to stay on the airborne instrument during the flight. The /85 amount of information to be processed during this period would be the same, even under different conditions. That is, it can be thought that the degree of difficulty x the number items memorized = a fixed value. Therefore, Figure 4 shows the amount of information that can be processed by all subjects, if the contents of each are converted into an amount of information. The whole amount of displayed information is indicated in the upper row in each colum of conditions. As we see in the calculation result in Table 3, it becomes gradually more difficult from condition 1 to 8.

However, among them, the items which were processed within the first 5 seconds (middle row) had reduced conditional variances, different from the number of items, whose amount of information is 112.16 ± 12.68 bits. If the parts of an item are correct, as in the case in which 450 feet was answered for ALT 350 feet, if the 10 decimal and 1 decimal are assumed to have been processed, it would become 131.48 ± 9.65 bits with the adjustment for the correctly answered parts.

The figures in ( ) indicate the number of subjects who answered

Tab. 5 Amounts of information of static models used in Exp. II (value equivalent to bit).

Condition		DH	GS	TAS	ALT	Pitch	Bank	Speed	G Slope	Course
1	Content	100	150	150	100	0°	0°	Normal	Normal	Normal
	Value	3.0	6.2	6.2	5.3	1.6	1.6	1.6	1.6	1.6
2	Content	150	150	155	900	5°Up	0°	N.	N.	N.
	Value	6.2	6.2	9.4	5.3	3.6	1.6	1.6	1.6	1.6
6	Content	110	150	145	350	0°	5°Right	N.	N.	Left
	Value	6.2	6.2	9.4	8.5	1.6	4.6	1.6	1.6	3.6
7	Content	140	140	135	420	7° U.	5°Left	Slow	Above	Right
	Value	6.2	6.2	9.4	8.5	5.6	4.6	3.6	3.6	3.6
8	Content	130	193	208	852	2°Down	3° L.	Fast	Below	L.
	Value	6.2	9.4	7.2	11.7	5.6	6.2	3.6	3.6	3.6

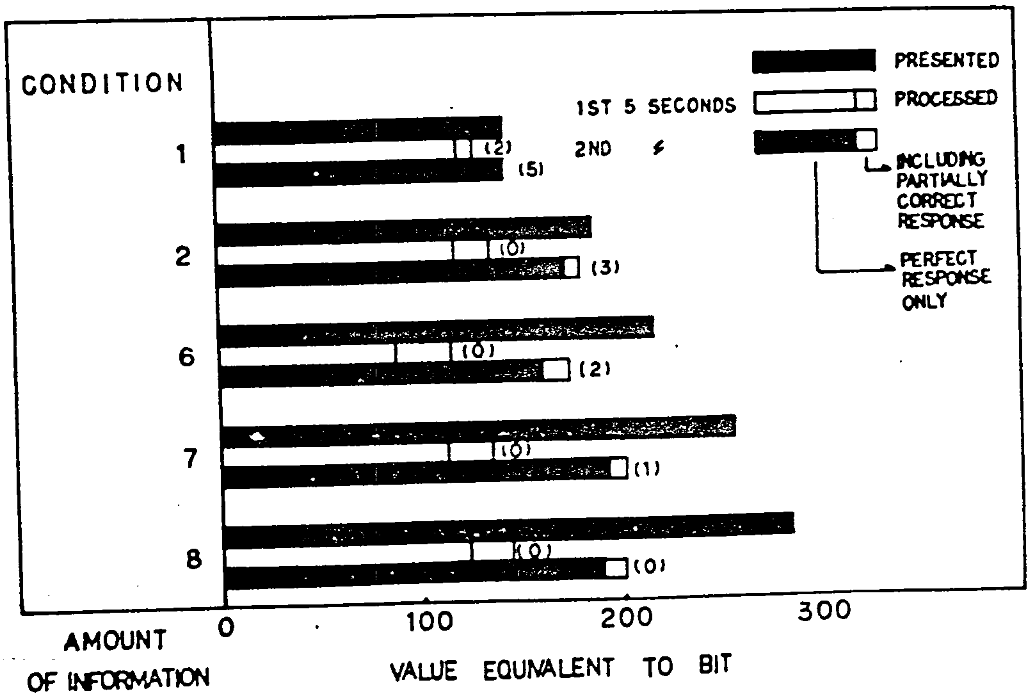

Fig. 4 Amounts of information presented and processed in the models of Exp. II.

the 9 items perfectly within 5 seconds, and 2 subjects answered the all 9 items perfectly for condition 1. This means a surplus of processing capacity at the nerve center. Consequently, the value of the above processable amount of information increases. However, it is surmised that 130 bits/5 subjecjts = about 25 bits should be the processable amout of information for an individual.

As for the processing capacities after the second 5 second-presentations, there are seeming variances between conditions. However, it can be known from the numerical values in (   ) that all the subjects gave correct answers to condition 1, although they all missed condition 8. Accordingly, they could easily process condition and 1 and 2, and were ready for more. The amount of information that was processed for condition 7 and 8 was anout 200 bits/5 subjects, from which about 40 bits can be infered as the processable amount for a subject. /86

If the amount of information that can be processedis proportionate to time, the amount processed in the first 5 seconds and that in the second 5 seconds should be the same. However, the ratio is 25:40-25÷5:3, and it shows that a fair amout of information processing and memorization were completed in the first 5 seconds. Perhaps, the second 5 seconds were spent for things like checking the memories with the contents of the model. Therefore, it can be thought that the memorizing capacity increases in a negatively accelerated way in the course of time.

According to the study done by Sperling, G. et al. (1971), the number of letters that can processed stays as 7 letters, and the number of letters has no relation to the amount of information conveyed by the letters. However, in observing the capacity to process relatively complicated information within two 5 second-presentations, with an interval that is close to the limit of so called short term memory as in this experiment, the meanings of the displays, i.e., the amount of information,is thought to have a part in the information processing

For the study of the impact of this amount of information on a dynamic activity like controling an airplane, a wider scope of study, including the theories of information and cognition, will be needed.

IV Summary

Refering to the integrated instrument EADI, with which the B-767 will be equipped, the following two experiments using the static models of the instrument for landing with ILS, were conducted.

Experiment I: The time to memorize, as quickly and perfetly as possible, the contents of eight models whose degrees of difficulty vary.

Experiment II: The contents of five models to be memorized, whose degrees of difficulty vary, were measured within two 5 scond-presentations with a 30 second-interval.

The main results were as follows. /87

1. In Experiment I, the average time to memorize the contents of models varied from 11.1 seconds to 67.9 seconds according to the relative difficulty of the models. ($p<0.01$).
2. Some subjects memorized the contents faster than others ($p<0.01$). The faster the subjects memorized the contents, the more errors they commited.
3. In Experiment II, there was a significant difference not among subjects but among models as regards the number of memorized items.
4. Generally speaking, the analogue information could be processed and memorized faster than the digital information concerning the number of correctly responded items.
5. The differences in the processed and memorized amount of information equivalent to bit were very small among the models. Information processing capability is estimated to be approximately 25 bits (equivalent) for the first 5 second-presentation, and 15 bits (equivalent) for another 5 second-presentation after a 30 second-interval.
6. The phenomena mentioned above suggest that the information processing capability increases due to the exposure time with negative acceleration.

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REFERENCES

1. Okabe, M. et al., "Togo Koku Keiki no kenkyu Shisaku (A study and and experiment of airborne integrated display)", Koku Uchu Gijutsu Kenkyusho Hokoku, NALTR-608, 1980

2. Allsopp, W. J., 757/767 "Electronic displays", International Aeronautical Symposium, Text No.XI, 1982

3. Stanley, N. R. & Corl, L., "Flight display dynamics revisited", Human Factors, 23(3), 341-353, 1981

4. Soliday, S. M. et al., "Terrain-following with head-up display", Human Factors, 10(2), 117-126, 1968

5. Tole, J. R. et al., "Visual scanning behavior and mental workload in a aircraft pilot", Aviation Space and Environmental Medicine, 53(1), 54-61, 1982

6. Jensen, R. S., "Prediction and quickening in perspective flight display for curved landing approach", Human Factors, 23(3), 355-363, 1981

7. Matula, R. A., "Effects of visual display units on the eyes: a bibliography (1972-1980), Human Factors, 23(5), 581-586, 1981

8. Grandjean, E. & Vigliani, E. (ed.), Ergonomic aspects of visual display terminals, Taylor & Francis, London, 1980

9. Oestreicher, H. L., "Information processing aspects of bionics", Lectures in aerospace medicine, 464-480, USAF School of Aerospace Medicine, 1967

10. Sakkit, B.,"Counting every quantum", Journal of Physiology, 223(1), 131-150, 1972

11. Swenssen, R. G. & Edwards, W., "Response strategies in a two-choice reaction task with a continuous cost for time", Journal of Experimental Psychology, 88(1), 67-81, 1971

12. Sperling, G. et al., "The maximum rate of scanning letters for the presence of a numeral", Science, 174, 307-311, 1971

13. Rumelhart, D. E., Human information processing, John Willy & Sons, New York, 1977. (Translated into Japanese by Ken Goryo, Nengen no Joho Shori, Saiensu Sha, Tokyo, 1979)

14. Neicer, U., Cognition and reality , W.H. Freeman and company, San Francisco, 1976. (Translated into Japanese by Furusaki & Murase, Ninchi no Kozu, Saiensu Sha, Tokyo, 1978)

15. Loftus, G. R. & Loftus, E. F., Human memory, The processing of

information, Lawrence Erlbaum Associates, Inc., New Jersey, 1976. /88
(Translated into Japanese by A. Ohmura, Ningen no Kioku, Ninchi Shinrigaku Nyumon, Tokyo Daigaku Shuppan Kai (Univeristy of Tokyo Press, 1980.)

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